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REVIEWS.

Genesis of Ore Deposits. Published by the American Institute of Mining Engineers, New York, 1901. 8vo., 806 pages, illustrated. Price, $6.00.

THE compilation and republication of the papers recently presented to the Institute, and bearing on the genesis of ore deposits, has resulted in a notable volume. Beginning with the famous treatise presented by Professor Franz Pošepný at the Chicago meeting of 1893, and including the discussions at that and the succeeding meetings at Virginia Beach, Bridgeport, and in Florida, the volume is continued by an important group of papers read at the Washington meeting in 1900, with the succeeding discussions. It is concluded by a bibliography of additional papers on the same subject, read before the Institute, of 188 titles. The showing is a most remarkable one, and the volume includes a statement of almost every advance in knowledge of the principles of ore genesis made in America within the last ten years; not that in every case it is the fullest statement of the authors' views made here, but practically every advance made within that period in the study of American ore deposits, aside from regional work, is represented by an author's statement. The most notable exception is the comprehensive and valuable paper by Mr. Penrose on the "Superficial Alteration of Ore Deposits," contributed to this JOURNAL in 1894.[1] In all, twenty-two contributors are listed in the table of contents of the volume. There are eleven general papers and twenty-one criticisms or discussions. The full list of authors is as follows: R. W. Raymond, Franz Pošepný, W. P. Blake, Arthur Winslow, T. A. Rickard, Horace Winchell, John A. Church, S. F. Emmons, G. F. Becker, F. M. F. Cazin, Joseph LeConte, C. R. Van Hise, Walter Harvey Weed, Waldemar Lindgren, R. Beck, L. de Launay, Arthur L. Collins, H. Foster Bain, Charles R. Keyes, Frank D. Adams, J. H. L. Vogt, and J. F. Kemp.

Although the whole volume has been edited, much of it translated, and most of it obtained by the personal solicitation of the secretary of the Institute, Mr. R. W. Raymond, it is characteristic of his modesty that his name appears in the volume only among those of the contributors. Nevertheless, in preparing the volume, Mr. Raymond has performed a service which his fellow-workers will more and more appreciate as the work comes to assume its rightful place; that of the standard statement of modern views on ore deposits.

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[1] JOUR. GEOL., Vol. II, pp. 288–317.

Covering, as it does, practically a decade of discussion, and being made up, as it is, of the statements of so many workers, it is in a peculiar degree a summary of present belief with just enough of discarded theory to give a proper perspective. The period from 1893 to 1901 has been particularly fruitful in the study of ore deposits, and, as is so often true, much of the discussion which has led to the clearing up of certain phases at least of the problem of the genesis of ores, came from the clear and unequivocal statement of an extremist; one, furthermore, whose ideas were radically opposed to those most generally current at the time. Up to 1893 American scientific opinion was strongly committed to the doctrine of lateral secretion; not, however, exactly in the sense proposed by Sandberger in his famous treatise[1] defining that doctrine. A characteristic expression of the broader American view is that of Emmons in his report on the Leadville district.[2] According to this view, ore deposits in general represent concentrations made by underground waters, the material being derived from the leaching of the country rock, not necessarily of the immediate vicinity. The waters were believed to be meteoric in origin, and more or less closely connected with the ordinary surface circulation.

In 1893 Professor Pošepný, with charming spirit, and fortifying his argument with many illustrations drawn from notes accumulated during a long and intimate study of ore deposits, combated this view most vigorously. Beginning with a clear and accurate analysis of the subterranean water circulation, he discriminated sharply a vadose or shallow circulation from a deep circulation, basing the distinction mainly upon the chemical constitution and effects of the two waters; a difference already clearly recognized and made use of in America by both Le Conte and Chamberlain, but not generally recognized as fully as it deserved. As characteristic of the difference between the waters of the two circulations, and most significant for purposes of the discussion, it was pointed out that the water of the vadose circulation in only the rarest instances deposits sulphides, while these salts are the characteristic deposit of waters of deep circulation. Since the bulk of the ore deposits, neglecting certain clearly recognized but minor classes over which there is no dispute, are made up of sulphides or their alterative products, it was held that the ores must have been made by the deeper circulation, and that the waters making the deposits must have been "ascending." In the earlier portion of the paper there are statements making clear the relations between the two circulations, and showing that one is but the counterpart of the other (pp. 27–28); there are later numerous statements which throw the matter into confusion (pp. 39, 56, etc.) While there is not such a clear statement as would be desirable, we are led to infer that the waters of the deep circulation are in some mysterious way cut off from and different from those of the shallow circulation, and that they are connected with a certain deep region, or barysphere, "the peculiar home of the heavy metals." The existence of this region is inferred from the usual calculations based upon the difference in density between the earth as a whole and the rocks of the surface of the earth. The very existence of a barysphere, in the sense of a central region of the earth heavier by reason of a greater abundance of the heavy materials, is to be questioned,[1] however, on many grounds.

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[1] *Untersuchungen uber Erzgange*, Weisbaden, 1885.

[2] *Monograph XII, U. S. Geol. Surv.*, Washington, 1886.

In the discussion of Pošepný's paper, which followed its presentation, some of his criteria were discredited, and Rickard struck the keynote when he stated that neither ascending nor descending was the proper term to apply to the ore-depositing waters, but that circulating was the true descriptive term. This was characterized by Pošepný as "a step backward." The most trenchant and significant criticism, however, was that of Professor LeConte, who showed the great improbability, if not actual impossibility, of any surface waters penetrating to the depth of the assumed barysphere, and who then pertinently inquired, If the waters which deposited the ores were not meteoric in origin, where did they come from? Were they constituent waters originally occluded in the primal magma? This is on its face highly improbable, particularly in view of the fact, so clearly recognized by Pošepný, that any ore deposit necessarily indicates the passage of a considerable body of water through the space now occupied by the ore.

At the close of the discussion, then, we are left with the conclusion that ore deposits, in general, are formed by the circulation of under-

[1] See particularly Arrhenius, as cited by VOGT, *op. cit.*, p. 638.

ground waters, the material being gathered from the rocks through which the waters pass, and that the sulphide ores are formed principally by the returning or ascending portion of the circulation. This conception, amplified and defended with many arguments and examples, is the keynote of the paper by Van Hise, which forms the natural beginning of the second part of the volume. Since Professor Van Hise's views have already been presented in this JOURNAL,[1] no review of them need be made here.

The criticism of Van Hise's views has been principally along two lines: (1) Is the conception presented by him of a universal underground circulation moving in obedience to gravitative stress a true one? and (2) is such a circulation competent to account for ore bodies such as actually occur without calling in the very frequent and active agency of eruptive forces? It appears to the reviewer that, to a considerable extent, the criticism is based upon an erroneous understanding of the hypothesis, and to a minor extent upon a misconception of facts. A universal underground water circulation does not necessarily mean universally saturated rocks. The great difference in permeability of rocks precludes their having an equal water content. If a larger emphasis be placed upon the influence of impervious strata, the supposed difficulties largely disappear. Professor Kemp cites a number of deep workings which are dry (696–701), and states a belief that the amount of water which penetrates to depths is probably comparatively small. Such citations, however, are only significant when the full details of each case are fully understood. For example, the Congress mine in Arizona has been cited, by another, as an instance of a very deep mine which is notoriously dry. The illustration loses its force, however, when it is remembered (1) that the region is one in which the water level is everywhere far below the *present* surface, and (2) that the Congress vein is a very shallow dipping one. "Very deep," as measured along the vein, is, accordingly, not "very deep" as measured vertically. Again the Vindicator, Hull City, and neighboring mines at Cripple Creek go down a thousand feet or more in perfectly dry ground, but they start only a short distance laterally, but at a considerable altitude above Wilson Creek. Furthermore, anyone visiting the workings will at once see the clearest evidence of the former action of underground waters; in this case evidently oxidizing surface waters.

[1] JOUR. GEOl., Vol. VIII, pp. 730–70, 1900.

Perhaps a still clearer example is that of certain mine workings in the Newhouse tunnel at Idaho Springs, Colo. This tunnel is driven north from South Clear Creek a distance of more than two miles under Seaton Mountain and toward Central City. It attains a maximum vertical depth of 1,710 feet, or approximately 2,200 feet, as measured along the dip of the veins. The slopes of the Gem workings in this tunnel are so dusty that there is difficulty in obtaining men who will work in them permanently, yet the month that the tunnel cut through this vein the men had to wear a full outfit of rubber boots, slickers, and rubber hats, and the tunnel drift still yields a notable flow of water. When the Addudle vein was cut, approximately a year ago, there was another small flood, and to this day the vein is raining into the tunnel steadily. In this instance, despite the steady downpour, the old surface workings are as full of water as ever. That the waters encountered in the tunnel belong to the ordinary underground circulation and come from the surface is proven by their oxidizing character. In general, along the tunnel the main flow of water comes from the veins, but nevertheless there seems to be a minor but steady seepage through the country rock. A rough measure of this seepage is given by certain work in the Franklin mine. The first of February, this year, the sixth level yielded a flow of approximately 7,000 gallons per day. Since then the drifts have been extended 250 feet, adding approximately 5,000 square feet of surface for seepage, and not intersecting any important cross veins or fractures, and yet the flow has slightly more than doubled. Since there has been no corresponding increase in the amount of water elsewhere, it seems clear that the larger flow is due to the greater surface. The fifth level of this mine, by the way, since pumping began on the sixth, is dry, but on the first level there is a drift not connected with the lower workings, full of water. Clearly in this case the different portions of the vein matter vary greatly as regards permeability. Cross-cut tunnels generally yield little water except as they intersect fractures; but I know of none which does not have a water box along the bottom and a steady stream of water flowing through it; that is, while the flow is practically confined to the fractures, the rock, measured in bulk, none the less contains water in quantity. The evidence, then, points to a widespread underground circulation, though there are admittedly dry or impervious beds, and admittedly measurable flows are nearly always confined to visible cavities.

It is furthermore pertinent to inquire, with Le Conte, if it be held that the waters from which the ores were deposited do not originally come from the surface, and if the "ascending currents" are not fed by equivalent "descending currents," what is the nature of this water, and whence its source? It is admitted by practically all students of the problem that the deposits in question are the work of waters of some sort.

The question whether the waters derive their motive force from gravitative stress is one which must be answered in each case with an eye to the facts of the particular case. Admittedly the friction between the moving fluid and the walls of the conduit decreases the pressure, and, supposedly at least, the friction might become so great as to wholly stop the flow. In the case of water moving through supercapillary tubes this cannot on the average be true, so long as the distance measured is vertical, and the tubes are approximately regular, since the pressure increases *pari passu* with the friction. The flow is further increased presumably by decreasing viscosity resulting from heat. It may be stated at once that probably, as it seems to the reviewer, the major flow concerned in the formation of ore deposits is that through supercapillary tubes. In the matter of flow through capillary tubes, there is some doubt, since the laws of such flow under high pressure seem not well understood; but if Poisenille's law be applicable, the result must be the same, since the flow is proportional to the pressure itself, which increases directly with the depth. Wherever the underground waters are in motion it is difficult to conceive of their not flowing in obedience to gravitative forces; except in very especial and particular instances where the little understood gaseous pressure may become operative.

In regard to the second question, whether ores are not more directly dependent upon the phenomena of vulcanism than would be inferred from a general reading of Van Hise's paper, it is but fair to state that he evidently recognizes these forces as important, though he devoted more space to less generally recognized phases of the problem. It has been tacitly assumed by all parties to the discussion that heated waters under pressure have been the main agents in collecting the material which makes up the ore bodies. The underground waters may become heated by (1) contact with volcanic rocks recently injected into the outer crust of the earth, (2) by contact with rocks heated by dynamic action, (3) by penetrating to a sufficient depth to absorb heat from the interior of the earth, and (4) by chemical activity between the water and the material in the rocks. The waters may come undei pressure (1) by increasing gravitative stress due to increased head as they gain in depth, (2) by expansion in confined space as a result of heat, and (3) by gaseous pressure, itself perhaps the result of chemical activity. With all these sources of heat and pressure available, the important point is to discover which ones have probably been operative to the largest extent. To the reviewer it seems clear that, as pointed out by Vogt and Kemp, the intrusion into the outer crust of the earth of molten rock from below has probably been the largest single factor in heating the underground waters. The distribution of the mineral districts in connection with the distribution of these eruptives and of hot springs affords a powerful argument for this conclusion. The close association of ore deposits, eruptive rocks, and hot springs has been so often pointed out as to need no further citation. The exceptions, such as the lead and zinc deposits of the Mississippi valley, have uniformly been found on careful study to differ in genesis from the more common type of sulphide ore deposits exemplified in the usual occurrence of the precious metals in the Rocky Mountain region.

A body of molten rock, forced up into the cooler mass above, must produce a profound disturbance of the ordinary underground circulation. Its quickening and vivifying influence is bound to be stupendous, and the marks of the intrusion are apt to be permanent. The underground waters of such a district will be warm for centuries after the magma itself has consolidated and become fixed in form and place. An instructive instance, and one believed not to be exceptional, is that of Idaho Springs, in Colorado. There are here hot springs which presumably are the last surviving mark of volcanic activity in the district. The youngest rocks present are certain andesitic dikes, whose age is approximately fixed by andesitic débris found in Tertiary beds near the mouth of Clear Creek Cañon, at Golden. Since the intrusion of these dikes the whole country has been profoundly sculptured, and the interval must certainly have been a very long one, yet the underground waters, as shown by the hot springs, still penetrate to some portion of the uncooled rock. The ore bodies of the district are closely related to these andesites; indeed, the veins usually occur along the contact of the andesite and the Archean country rock, and in places are merely mineralized portions of the andesite itself. So far as is known there are no considerable ore bodies in the surrounding Archean not connected in some way with the andesite. Furthermore, no considerable mining district in Boulder, Gilpin, or Clear Creek counties occurs except where these andesites are present, even though the same Archean country rock is everywhere present, and in all probability was subjected to the action of ordinary underground waters for many times as long before the intrusion as after. Under these conditions the connection of the ore bodies with the disturbance of the underground circulation by the intrusion of the eruptive rock can hardly be doubted. The possibility of their being formed by normal underground circulation counts for little as against the fact that, in the long time from Archean to Tertiary, they were not formed, and in the relatively short time since, under the new conditions, they were.

It is equally clear, however, from a study of the ore bodies, that the process of their formation occupied a long period, as measured by ordinary standards. The ores are associated with the most altered portions of the eruptives. They occupy often fissures in the latter which could only have been formed after the rock had consolidated and cooled sufficiently to be amenable to the ordinary stresses existing in the rocks of the surface of the earth. The halogen elements are conspicuously absent, and there is no known reason for inferring that pneumatolitic action was prominent when the ore bodies were formed. It may be added that the veins are typical "fissure veins" carrying sulphide ores; the very class of deposits principally under discussion.

Among the many phases of ore bodies, aside from the problem of their primary genesis, which are discussed in the volume under review, there are none more important than the secondary enrichment of the sulphides, and the metasomatic processes in fissure veins. The first is discussed in separate papers of Emmons and Weed and in portions of papers by Van Hise, Rickard, and de Launay. The second is treated in considerable detail by Lindgren.

Starting from a disposition to question Pošepný's dictum that sulphides were not formed by the waters of the vadose circulation, Emmons, Weed, and Van Hise have independently worked out the process by which the sulphide ore bodies at and near the water level become enriched by material carried down from the oxidized ores above. The process depends principally upon the relative affinity of the various metals concerned for oxygen and sulphur, by which, for example, iron sulphide comes to act as a precipitant for zinc and lead when the latter are present as a sulphate. The process is well founded on known principles, and the phenomena accounted for are among the most common and heretofore most puzzling encountered in mining. The solving of this difficulty is likely to be of the highest practical utility.

Mr. Lindgren's paper on metasomatic processes gives sharp definition to many heretofore hazy phenomena and will be of considerable utility both in the development of theory and practice.

In general, the volume is notable in that for the first time the results of recent investigations in physical chemistry are applied to the solution of the problems of ore genesis. The results attained are most promising, and open up enticing vistas of what may be expected from further investigations along these lines. For example, the question may be asked whether, in seeking an explanation of the chemical problems involved, we have not relied too exclusively upon the influences of heat and pressure. If we keep in mind the very large place in the field of research which the diminutive ion now holds, and the close relations obtaining between ions and electric forces, one may well question whether here is not a fruitful field for investigation. The startling results already obtained in physiological investigations by studying the operation and effects of the electro-motive force hint at perhaps equally important results awaiting the investigator in other fields.

H. FOSTER BAIN.

IDAHO SPRINGS, COLO.

SUMMARIES OF THE LITERATURE OF STRUCTURAL MATERIALS. I.

EDWIN C. ECKEL.

UNDER this heading the writer purposes to summarize at intervals the literature relating to the economic geology of building stone, road materials, cements, lime, gypsum, clays, etc. Except when the word "comment" expressly appears, the matter presented will be simply a summary of the statements and opinions appearing in the paper under discussion. The writer will endeavor to indicate briefly the scope of each paper, following this by a résumé of the *original* matter contained in it.

BABCOCK, E. J. *Clays of Economic Value (in North Dakota).* First Report North Dakota Geol. Surv. Pp. 27–55, 3 plates, 1901.

The clays of North Dakota are derived from the Pleistocene, the Laramie, and the Fort Pierre division of the Cretaceous. The Pleistocene clays include the yellow